AIR CORPS INFORMATION CIRCULAR

(AVIATION)

PUBLISHED BY THE CHIEF OF AIR CORPS, WASHINGTON, D. C.

Vol. VI May 21, 1927 No. 586

STUDY OF BALANCED RUDDERS

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February 16, 1927

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON
1927

CERTIFICATE: By direction of the Secretary of War the matter contained herein is published as administrative information and is required for the proper transaction of the public business.

STUDY OF BALANCED RUDDERS

OBJECT

The object of this study was to discover to what extent the rudder can be balanced without causing pilots to complain of an overbalanced condition.

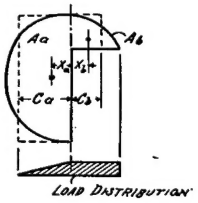
DISCUSSION

The dimensions of the various rudders in use on military airplanes were collected and an expression was developed to show the relative extent to which these rudders are balanced. The development of this expression assumed a uniform load distribution on the balanced portion and a gradually decreasing load from the hinge to the trailing edge. The coefficient K_b is, therefore, a ratio of the balanced area to the area aft of the hinge, due weight being given to the effectiveness of both areas. Pilots observations on the action of these rudders were also obtained and are given under the heading of "Remarks" in the table below.

CONCLUSIONS

This study shows no definite relation between the balanced coefficients and the pilots remarks. It may, therefore, be that rudders which are reported as overbalanced are really not overbalanced, and that other yaw characteristics of the airplane have resulted in producing that impression on the pilot. Again it may be that the shape of the balanced area influences its effectiveness in a way which we are unable to understand, still another possibility is that the area aft of the hinge may be shielded to various extents in the different airplanes by the fuselage, stabilizer, and elevators, also to an extent which we can not quantitatively determine. It is noteworthy that the XO–6 airplane has the smallest balance coefficient and yet is criticized by the pilots for being overbalanced. In view of our further study of the yaw characteristics of this airplane it is fairly safe to conclude that the overbalanced feeling is due to certain irregularities in the yaw moment curves for which either the nose of the airplane or the nose of the fin may be responsible. It is also worthy of note that the DH–4, the rudder characteristics of which are satisfactory, shows the highest value of balance coefficient and that this coefficient is more than three times as great as that of the alleged overbalanced XO–6.

DATA ON RUDDER BALANCES OF VARIOUS AIRPLANES



A_t = Total Area of Rudder
A_a = Area aft of hinge center line
A_b = Area of balance fore of hinge center line
C_a = Mean Chord of A_a
C_b = Mean Chord of A_b
[1] $X_a = \frac{C_a}{3}$ = Dist. to C. P. of A_a (approximate)
X_b = Distance to center of area A_b
$K_b = \frac{\text{Moment of Load on } A_b}{\text{Moment of Load on } A_a} = \frac{2\,A_b\,X_b}{A_a X_a}$

Airplane	Rudder	Remarks	Reference	A_t	A_a	A_b	C_a	C_b	X_a	X_b	K_b
				Sq. ft.	*Sq. ft.*	*Sq. ft.*	*In.*	*In.*	*In.*	*In.*	
CO–6	Original	Overbalanced	Captain Brower	14.82	12.73	2.09	25.50	12.10	8.50	7.02	0.260
CO–6	Reduced	O. K	do	14.27	12.73	1.54	25.50	8.88	8.50	4.94	.141
CO–5	Present	O. K. (small A_t)[2]	Lieutenant Johnson	18.41	16.50	1.91	28.60	15.30	9.53	8.60	.209
CO–4	do	O. K	do	13.70	12.32	1.38	24.95	8.25	8.32	3.93	.106
CO–4		First article	do	9.35	7.69	1.66	22.15	10.12	7.38	5.24	.306
DH–4	Present	O. K	do	12.20	10.40	1.80	23.60	12.50	7.87	7.87	.346
O–1	do	O. K	do	11.80	10.60	1.20	22.00	10.13	7.33	5.94	.184
P–2	do	O. K	do	10.80	9.32	1.48	22.18	16.40	7.39	6.65	.286
A–1[3]	do	Overbalanced	Lieutenant Dichman	13.75	11.90	1.85	29.60	7.82	9.87	3.97	.125
	do	O. K	Lieutenant Johnson								
GAX–1	Original	Overbalanced	Mr. Laddon	36.40	30.54	5.86	46.90	20.85	15.63	12.51	.307
GAX–1	Reduced	O. K	do	34.00	30.54	3.46	46.90	23.70	15.63	14.20	.206
PT–1	Present	Very good	Lieutenant Johnson	13.32	11.98	1.34	28.80	16.05	9.60	8.24	.192
XO–6	do	Overbalanced	do	17.27	15.80	1.47	26.90	8.39	8.97	4.32	.089
XO–6	do	do	Lieutenant Hutchinson								
XO–6	Suggested change No. 1 by T. M. Co			14.92	13.65	1.27	25.00	9.50	8.33	5.09	.114
XO–6	Change suggested by McCook Field			14.49	12.65	1.84	26.50	14.15	8.83	7.33	.241

[1] Triangular distribution of load is assumed for A_a. Uniform distribution is assumed for A_b.
[2] Insufficient total area for control at low speeds.
[3] Ambulance.

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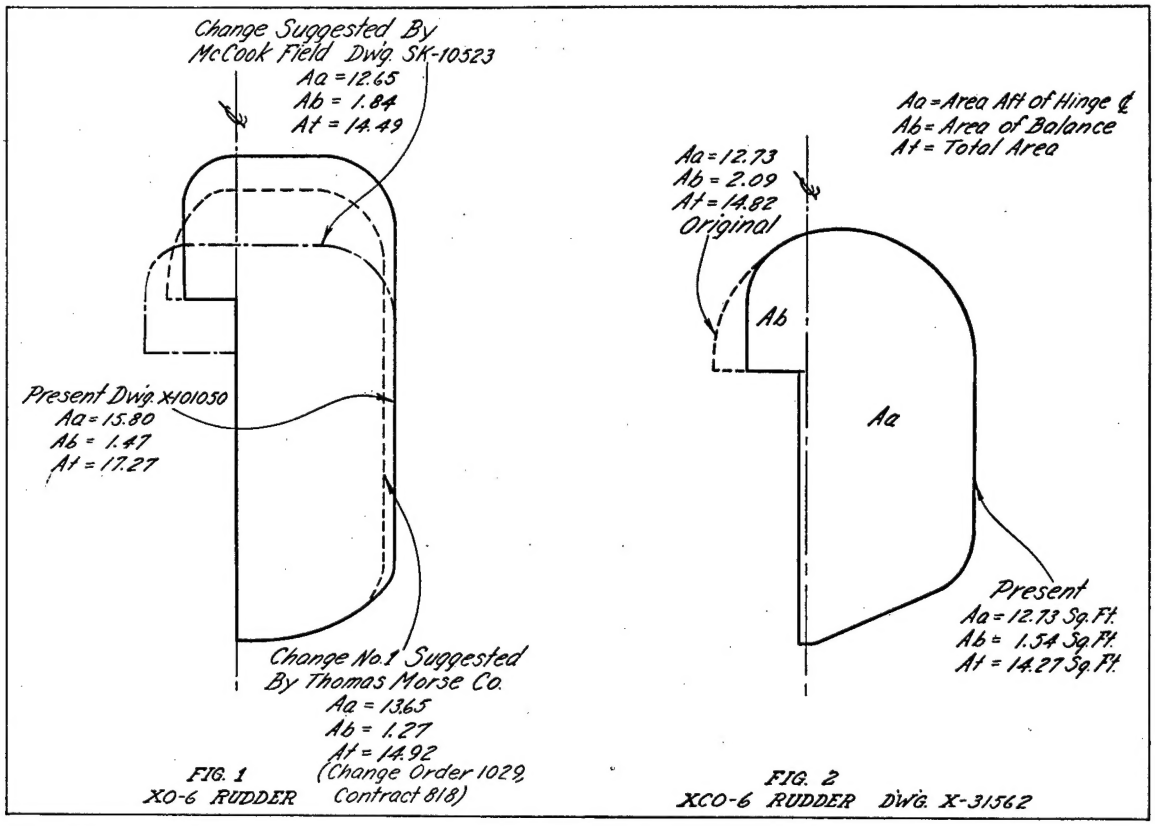


FIG. 1
XO-6 RUDDER

FIG. 2
XCO-6 RUDDER DWG. X-31562

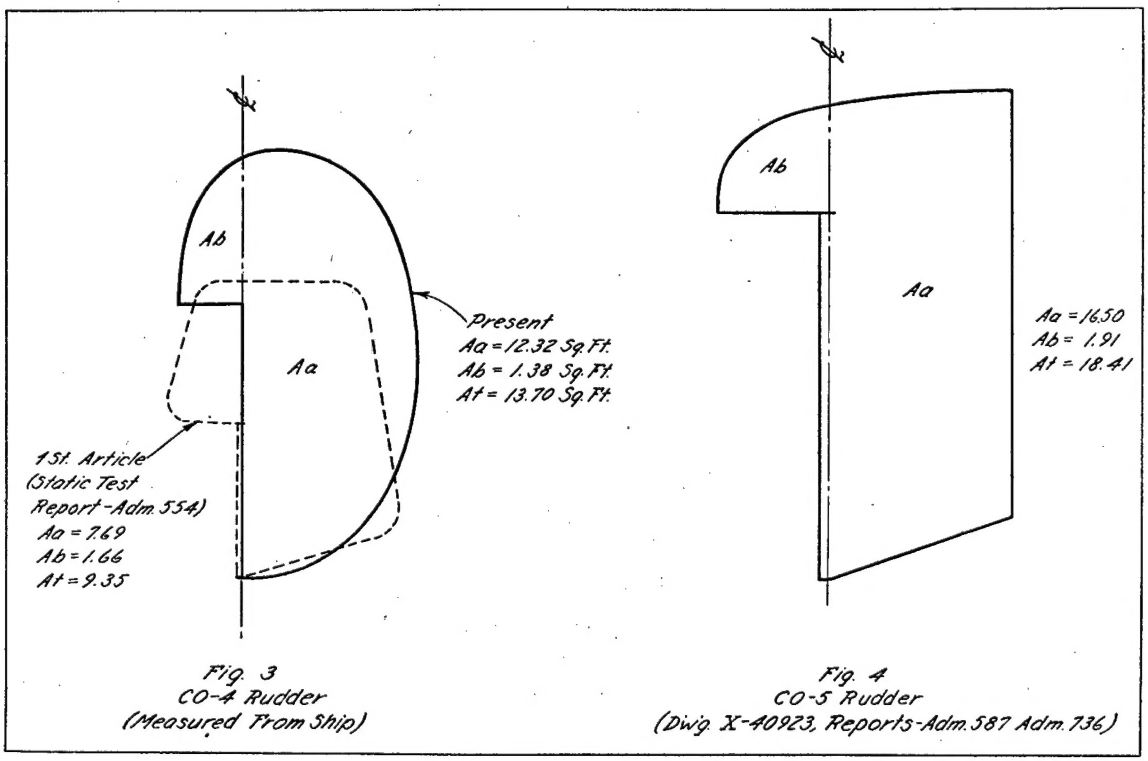
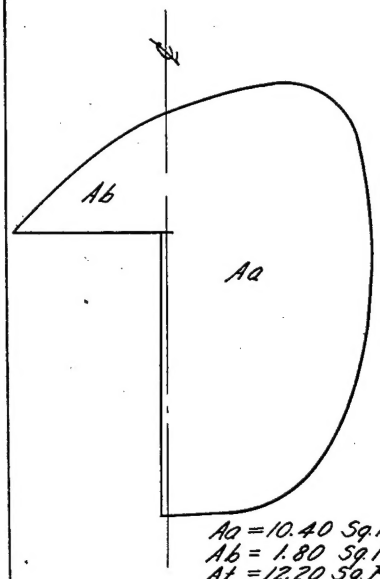


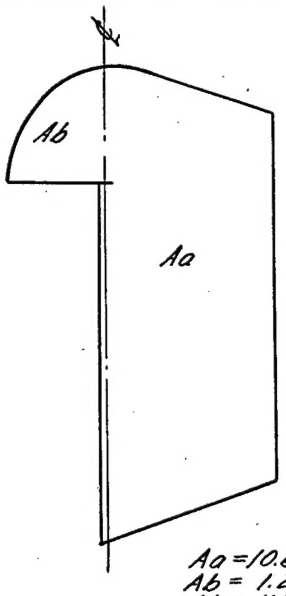
Fig. 3
CO-4 Rudder
(Measured From Ship)

Fig. 4
CO-5 Rudder
(Dwg. X-40923, Reports-Adm. 587 Adm. 736)



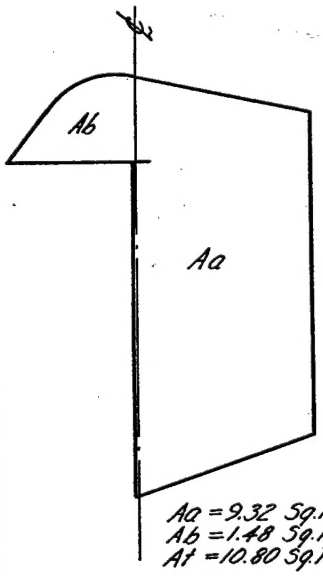
Aa = 10.40 Sq. Ft.
Ab = 1.80 Sq. Ft.
At = 12.20 Sq. Ft.

Fig. 5
DH-A Rudder
(Dwgs. 1299, 16534, 18088)



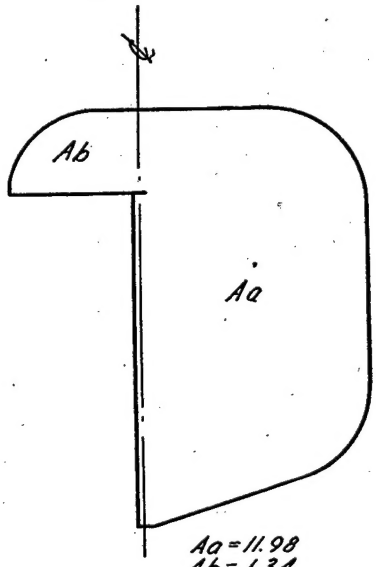
Aa = 10.60 Sq. Ft.
Ab = 1.20 Sq. Ft.
At = 11.80 Sq. Ft.

Fig. - 6
O-1 Rudder
(Dwg. Curtiss EX-34705)



Aa = 9.32 Sq. Ft.
Ab = 1.48 Sq. Ft.
At = 10.80 Sq. Ft.

Fig. 7
P-1 & P-2 Rudder
(Dwg. Curtiss EX-34102)



Aa = 11.98
Ab = 1.34
At = 13.32

Fig. 8
PT-1 Rudder
(Dwg. - Consolidated 1T003)

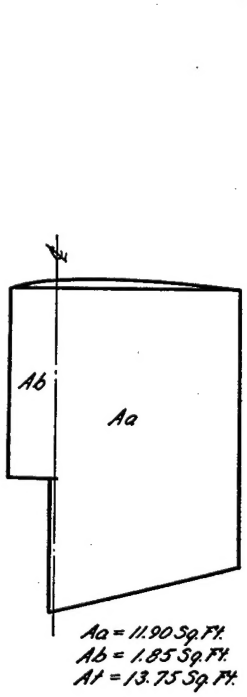


Fig. - 9
A-1 (Ambulance) Rudder
Dwg. COX-KLEMIN X-79068

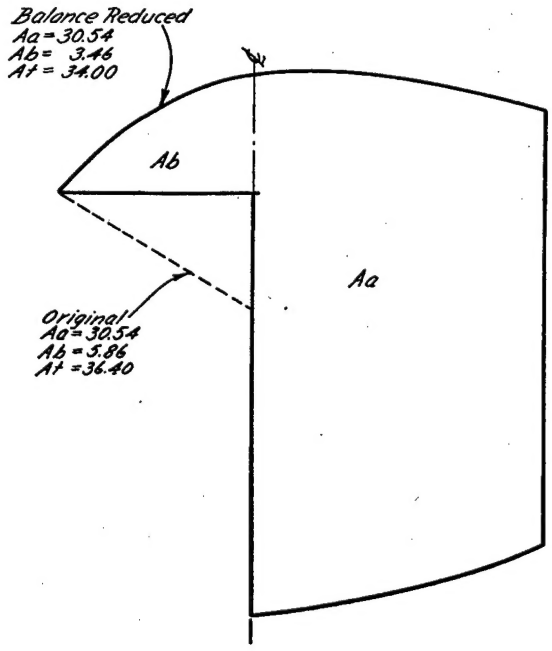


Fig. - 10
GAX-1 Rudder
Static Test Report ADM-474